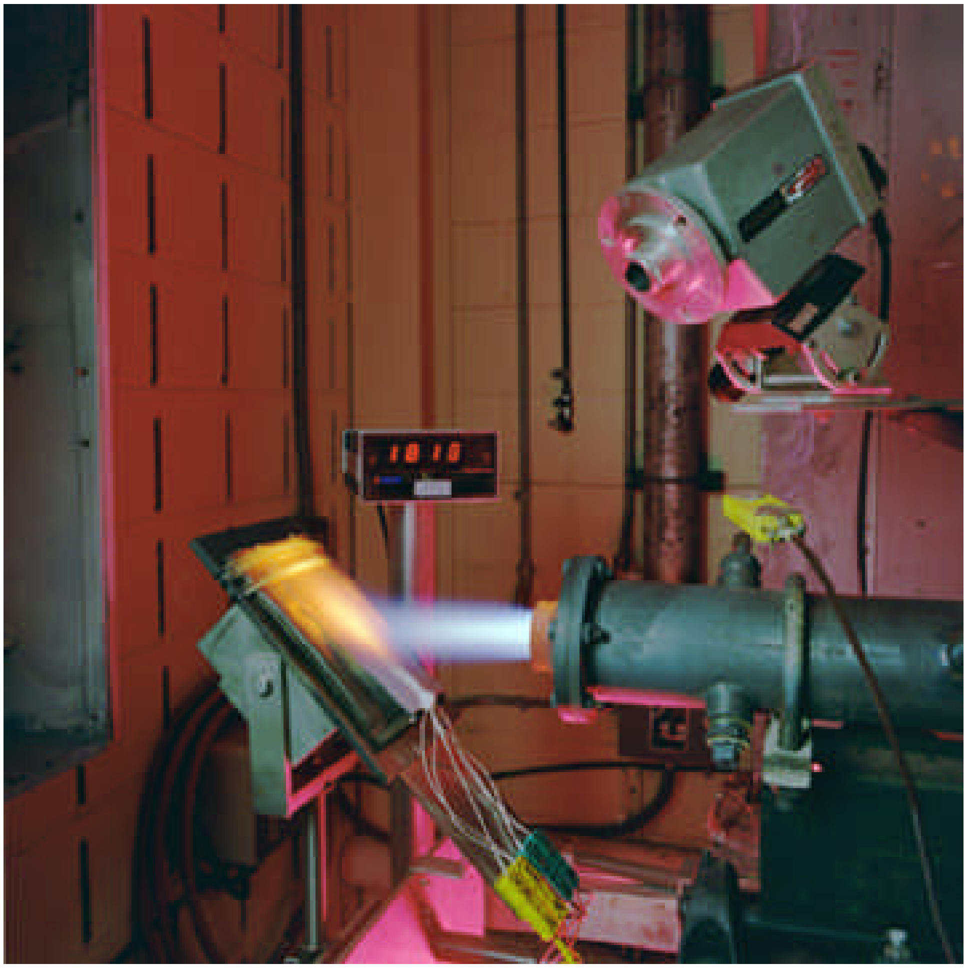
Attachment of Free Filament Thermocouples for Temperature Measurements on Ceramic Matrix Composites

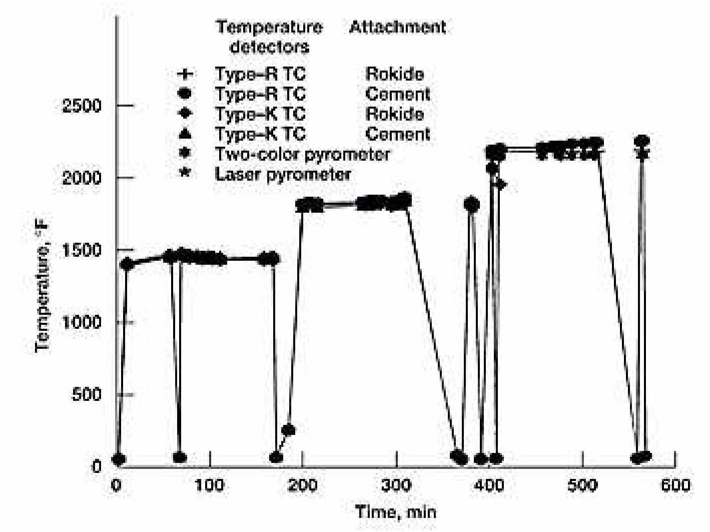
Measuring the temperatures of advanced materials, such as ceramic matrix composites (CMC's), in a hostile environment has been a difficult task because of the poor adhesion of the measurement systems. Commonly used wire thermocouples (TC) cannot be attached to such ceramic-based materials via conventional spot-welding techniques, and commercially available ceramic cements fail to provide sufficient adhesion at high temperatures. Although advanced thin-film TC's provide minimally intrusive surface temperature measurement and adhere well on CMC's, their fabrication requires sophisticated, expensive facilities and is time consuming. In addition, the durability of lead wire attachments to both thin-film TC's and substrate materials requires further improvement.

At the NASA Lewis Research Center, a new installation technique utilizing convoluted wire thermocouples (TC's) was developed and proven to produce very good adhesion on CMC's, even in a burner rig environment. Because of their unique convoluted design, such TC's of various types and sizes adhere to flat or curved CMC specimens with no sign of delamination, open circuits, or interactions-even after testing in a Mach 0.3 burner rig to 1200 °C (2200 °F) for several thermal cycles and at several hours at high temperatures. Large differences in thermal expansion between metal thermocouples and low-expansion materials, such as CMC's, normally generate large stresses in the wires. These stresses cause straight wires to detach, but convoluted wires that are bonded with strips of coating allow bending in the unbonded portion to relieve these expansion stresses.



An array of thermocouples applied to a CMC under test in a Mach 0.3 burner rig. The array was over 1800 °F when the photo was taken.

During testing, the temperature data taken from convoluted wire TC's were compared with those from Lewis' Mach 0.3 burner rig pyrometers. The SiC/SiC CMC temperature data measured by these TC's matched those of the facility's pyrometers to within 2 percent up to 1200 °C (2200 °F). However, the two-color facility pyrometer did not work with the transparent alumina/alumina CMC specimen, and the laser pyrometer, which has a signal wavelength of 0.865 µm, only worked to 1100 °C (2010 °F). No data were obtained from the type-K TC's when the CMC specimen temperature reached 1200 °C (2200 °F). This was due to the wire breaking, as revealed during the posttest examination. The type-R TC's, however, were still intact after all the testing.



Surface temperature of a SiC/SiC CMC measured by two type-R thermocouples, two type-K thermocouples, and two types of pyrometers.

This newly developed contact TC provides a way to measure temperatures when minimally intrusive measurement is not required. Convoluted wire TC's are much cheaper and faster to fabricate than less intrusive thin-film TC's. In addition, unlike thin-film TC's, these TC's require no preoxidation, no post annealing, and no surface treatment of the CMC substrate materials. They can, therefore, reduce the time and cost for sensor fabrication and installation. The same installation technique used for convoluted wire TC's can be applied to attach lead wires for thin-film sensors when minimally intrusive measurements are required. This technique should work for any low thermal expansion materials, such as ceramics (alumina, sapphire, zirconia, and silicon nitride), and other composite materials, such as carbon/carbon composites.

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